ECAL reconstruction and performance in Run 3

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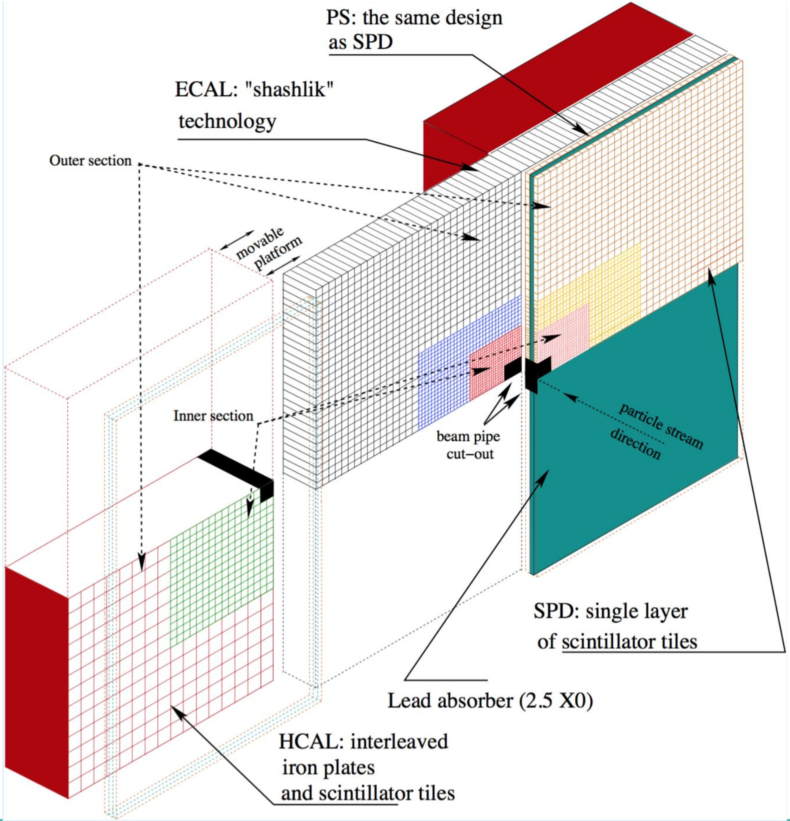
Calorimeter system in Run 3



- removal of SPD/PS system
  - used in L0 → not needed anymore
  - used for PID
- ECAL+HCAL are kept the same
  - update of electronics

Reconstruction and performance

Reminder

Neutral objects (γ, π^0) and electrons used in a variety of physics analyses

- Neutral objects: no info from tracking → only calo information
- Electrons: reco'ed as tracks BUT calo information critical for PID and Bremsstrahlung recovery

Strategy for Run 3:

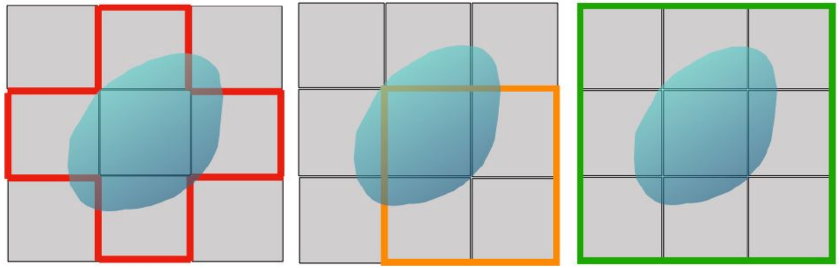
- Start from Run 2 reconstruction + improve where needed
- Calo reconstruction both in HLT1 (simplified) and HLT2 (full reco)

Clustering

1. search for local maxima in ECAL cells → seeds
2. apply masks around seeds: 3x3 default, studies with 2x2 and SC ongoing
3. find and correct overlapping cells: many more overlaps in Run 3
4. evaluate energy and position of barycenter, covariance and spread matrix

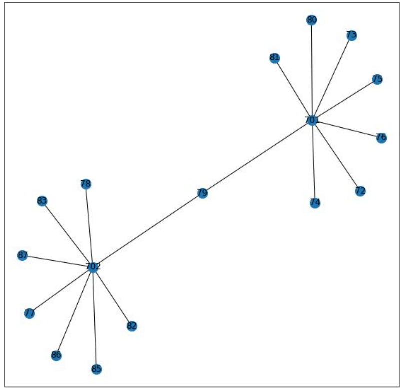
HLT1: no overlap correction (3), minimal 4

HLT2: New Graph Clustering for 1→3



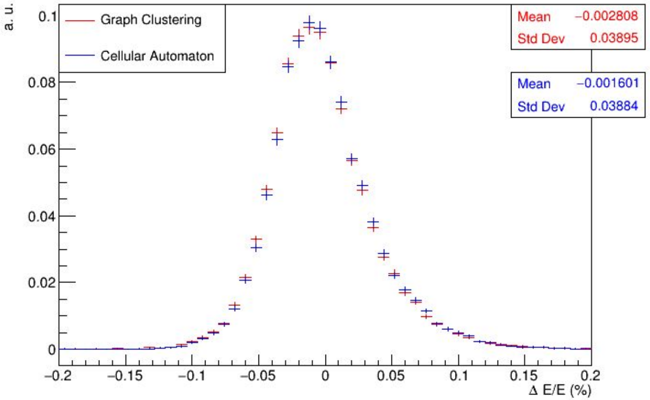
See talk by N. Valls

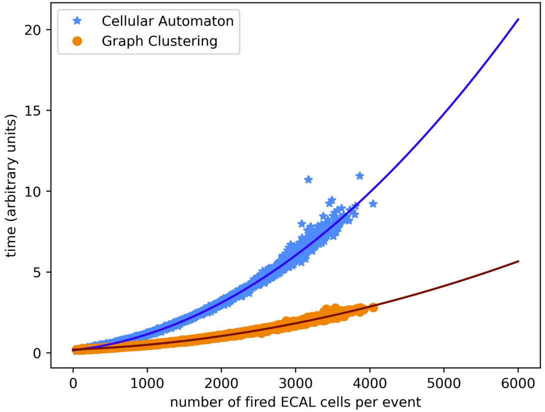
Graph Clustering



- Store ECAL digits in graph structure
- Insertion rules group together digits in same cluster
- Treatment of overlap clusters and merged π^0 candidates

Results: same physics performance with improved speed and scalability





*No energy corrections at this point

See talk by M. Van Veghel

Charged and neutral separation

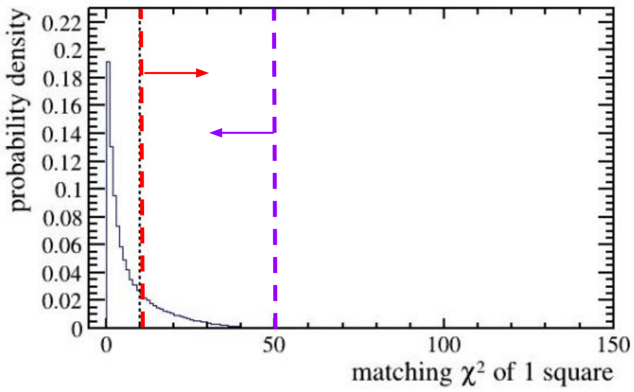
1. Extrapolate tracks to ECAL plane
2. find clusters in 1 cell-square around track projection (selective matching → speedup)
3. compute 2D χ^2 using size/sqrt(12) for cluster resolution

track position & covariance   cluster position & resol

$$\chi^2_{2D}(p) = (p_{tr} - p)^T C^{-1}_{tr} (p_{tr} - p) + (p_{cl} - p)^T S^{-1} (p_{cl} - p)$$

4. cut on χ^2_{2D} to classify clusters as neutral or charged
5. apply energy and position corrections to clusters depending on charge hypothesis

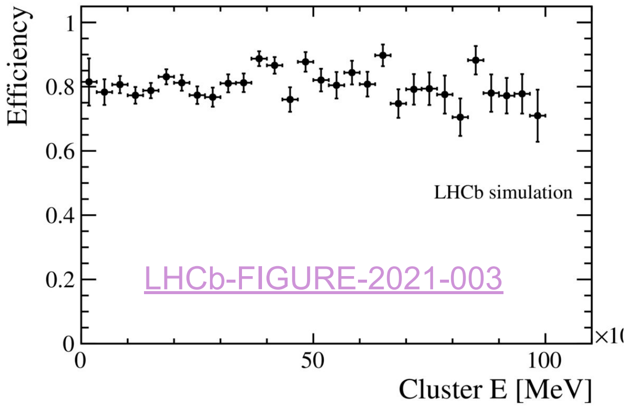
γ hypo: $\chi^2 > 10$
$e^{\pm}$ hypo: $\chi^2 < 50$



Clustering and classification efficiency

- Clustering: (85 ± 2)% reconstruction efficiency
  - > 90% of energy deposited in cluster and > 90% of cluster originated by signal
  - lower for γ from π^0: 20-30% for resolved/merged pions
- Classification (low stats test):

Quantity	Statistics	%
$\varepsilon\ e^\pm$	17	76 ± 10
$\varepsilon\ \gamma$	380	96 ± 1
f_{bkg} in $e^\pm$	30k	5.9 ± 0.1
f_{bkg} in γ	57k	39.7 ± 0.2



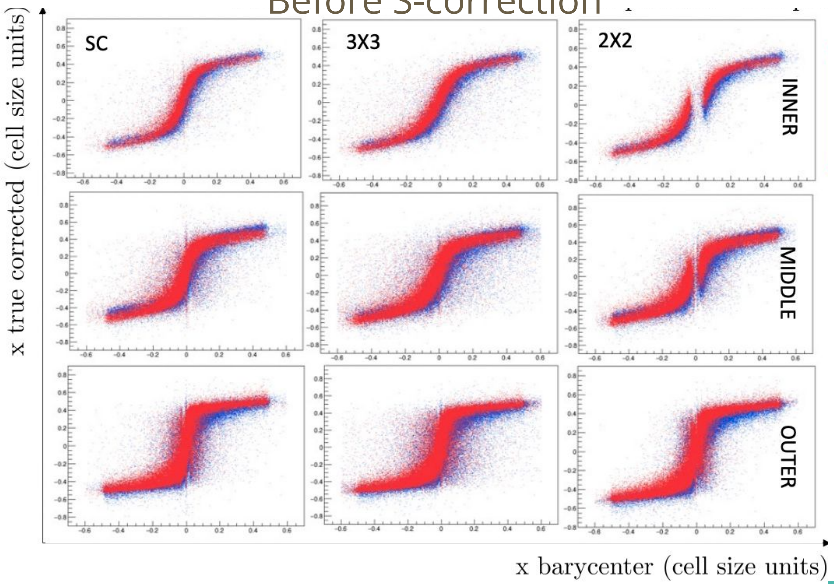
See talk by P. Garcia

Cluster masks and corrections (WIP)

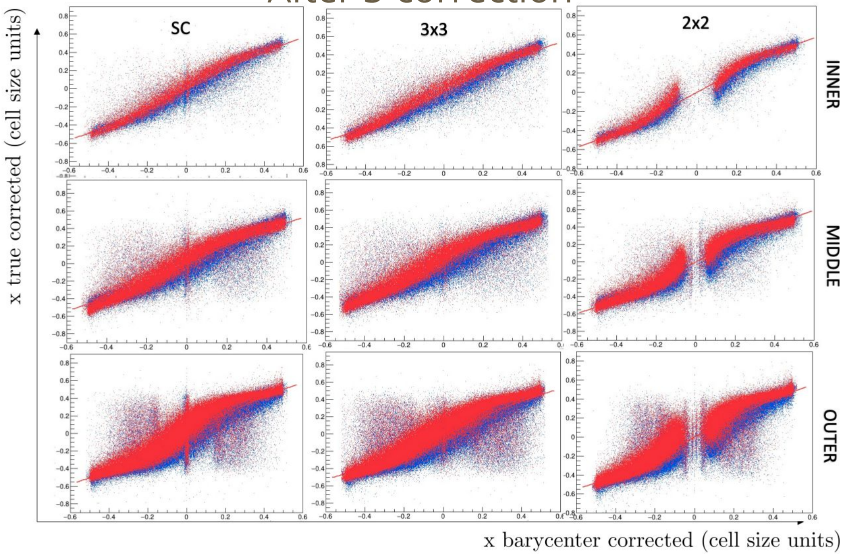
Systematic study of 3x3, 2x2 and SC masks and corresp. E, x, y, z corrections

- S-correction: correct bias due to exponential transverse shower profile

Before S-correction



After S-correction



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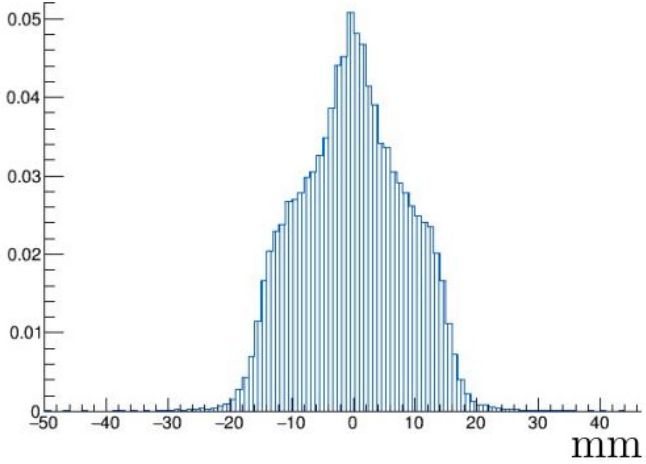
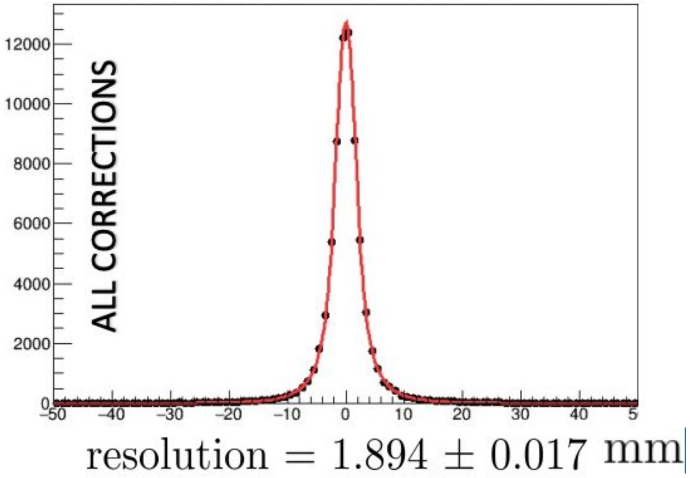


After S-correction



Warning: MC without pile-up!

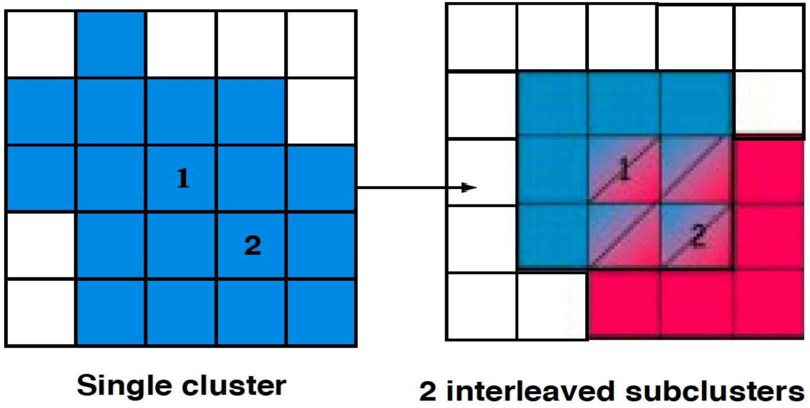
Neutral pions

For $p_T > 2$ GeV two photon clusters are merged together → merged π^0

1. Start from clusters from Graph Clustering
2. If 2 maxima in same cluster → split into 2 interleaved subclusters
3. Apply overlap and photon corrections to each

For $p_T < 2$ GeV separe clusters are found: combine single photons at analysis level

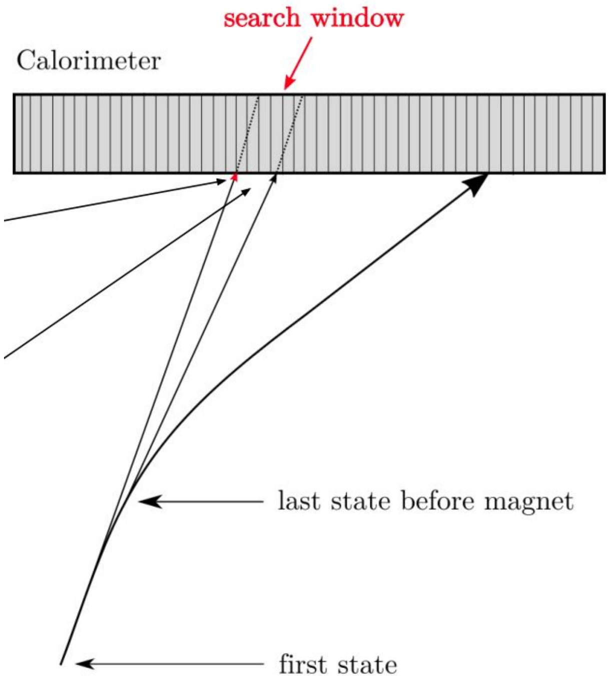
No optimisation done for Run 3, contributions welcome!



Electrons: Bremsstrahlung

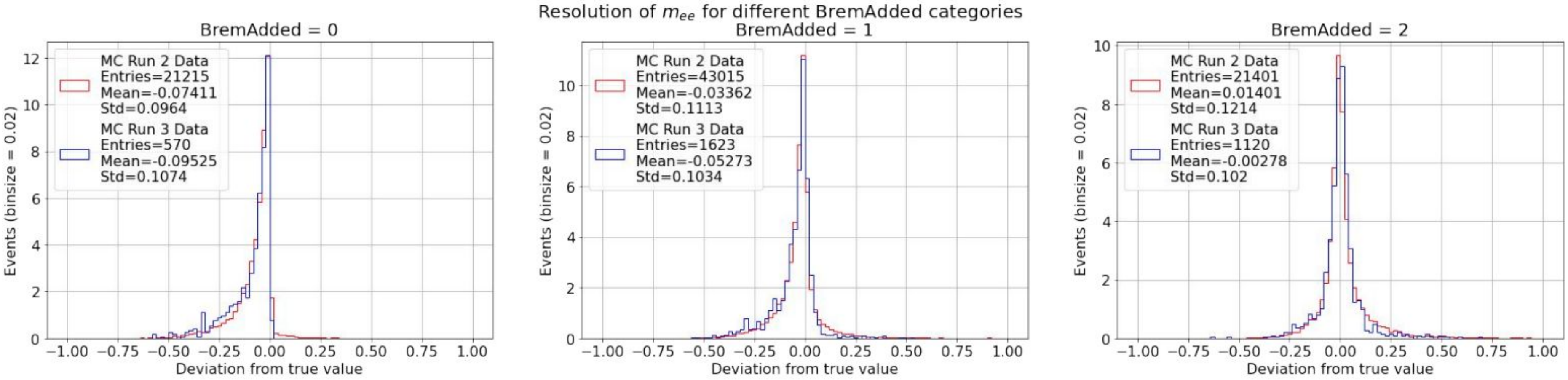
Affects p measurement + helps with PID

- p correction and PID now unified
- selective: cell E along 1st track state + cells at ShowerMax along search window
- Brem recovery applied at analysis level $\longrightarrow$ choice:
  - no-brem electrons
  - single brem-corrected electrons
  - e^+e^- cannot have same brem associated
- PID: additional info from $E_{bremtrack}$, angle



Electrons: Bremsstrahlung

- Similar performance to Run 2
- Overcorrection particularly improved

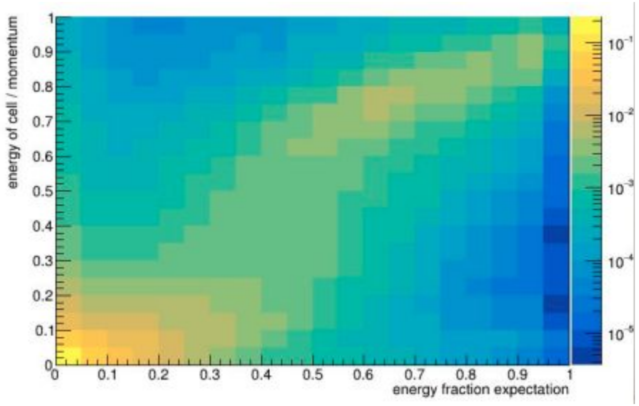


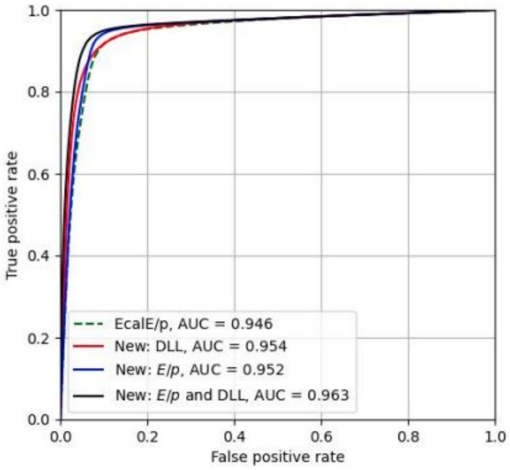
Electron PID

Calorimeter information is crucial:

- track-based shower info: E/p and per-cell DLL
- brem info: as presented
- HCAL: E/p, E across track trajectory

Improved performance wrt old variables!





Then combined with RICH and track information into DLL variables (ProbNN not yet available)

See talk by M. Calvo

Particle Identification for neutrals

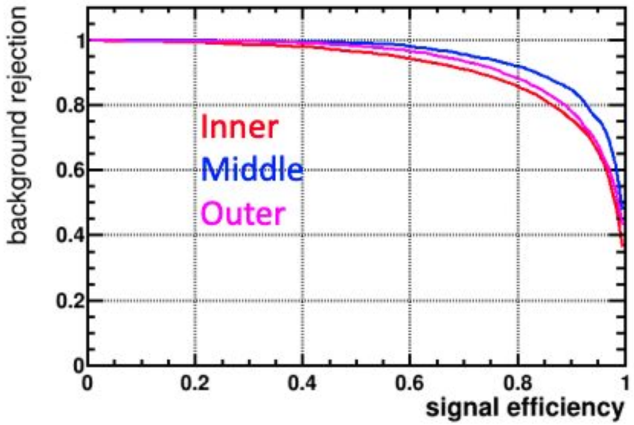
Two high level variables for Run 3:

- isNotH: separate photons from hadrons (except merged π^0)
- isPhoton: separate photons from merged π^0
  - for candidates with $p_T > 2$ GeV only

*isNotE gave poor performance in Run 3 → removed

Both use raw 3x3 deposits around seed as input

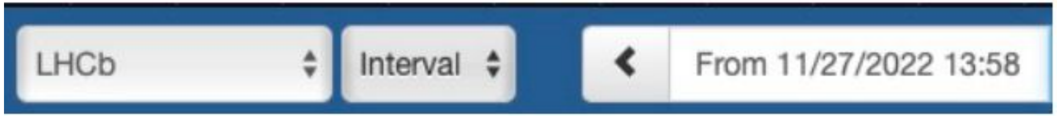
IsPhoton

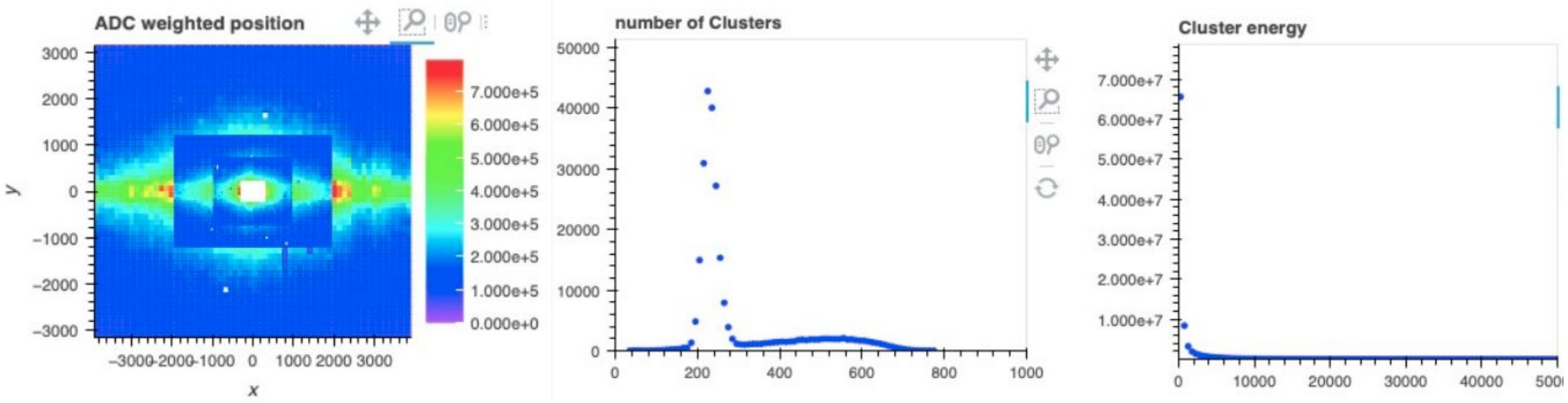


First Run 3 data

ECAL monitoring

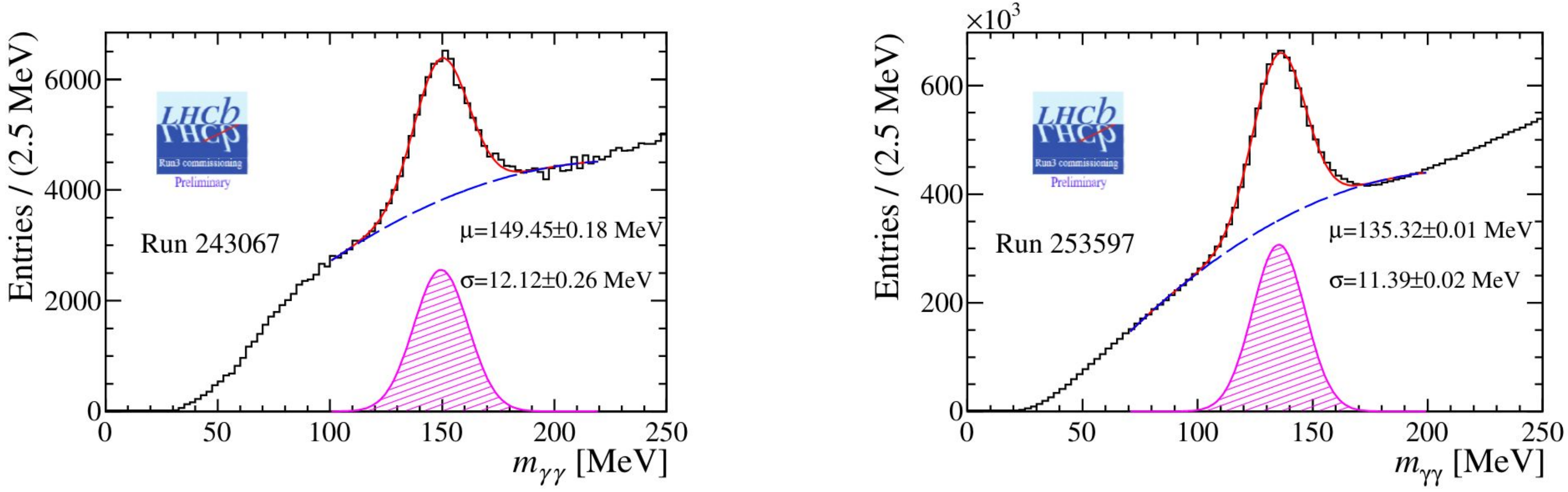
Seeing signal since July!





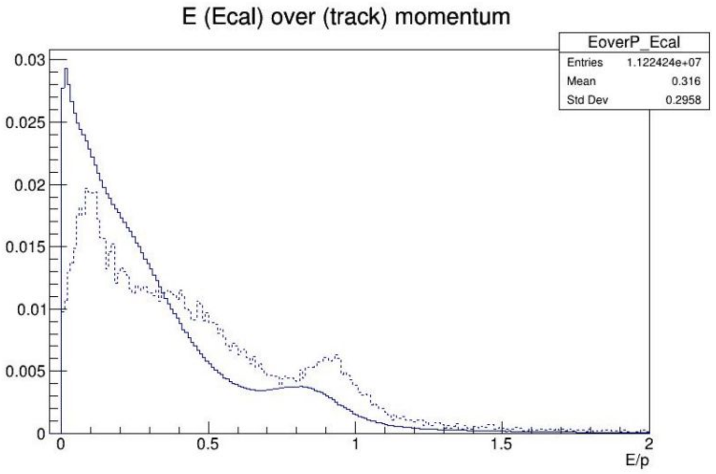
First signals: π^0

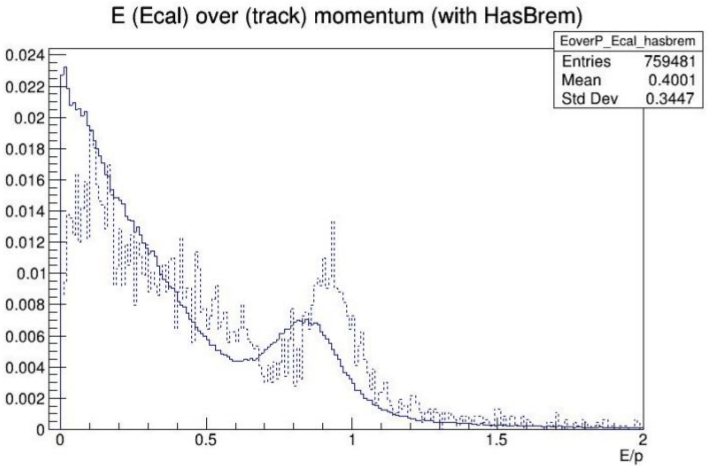
π^0 peak observed in August after adjustment of HV, much cleaner after 1st global calibration. Still room for improvement



Electron PID

- Run 252186 (full) compared to upgrade_Sim10aU1_minbias_xdigi (dashed)
    - Alignment: Scifi and velo v1
- Clear peak, purer after HasBrem requirement, slightly displaced (misalignment to be checked)





Summary

Reconstruction of neutral objects and electrons is in place for Run 3

- main changes to improve physics and computing performance with higher pile-up
- a lot of technical work behind the scenes: multithreaded framework, SOA event model, DD4Hep compatibility, etc.

Effect of pile-up mitigated by new algorithms and optimisations

- Similar electron PID and Bremsstrahlung recovery to Run 2!
- Tuning still ongoing for neutral objects

New contributors always welcome!

BACK-UP

Reminder

- photons reconstructed from ECAL clusters
- neutral pions from $\pi^0 \rightarrow \gamma\gamma$ decay $\rightarrow$ ECAL clusters again
- electrons: from tracking (resolution better at b-hadron energies)
  - calorimeter information crucial for PID
  - Bremsstrahlung recovery from reconstructed ECAL clusters

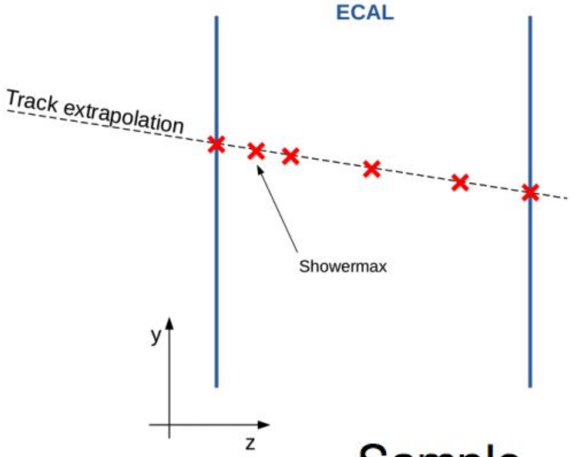
Documentation:

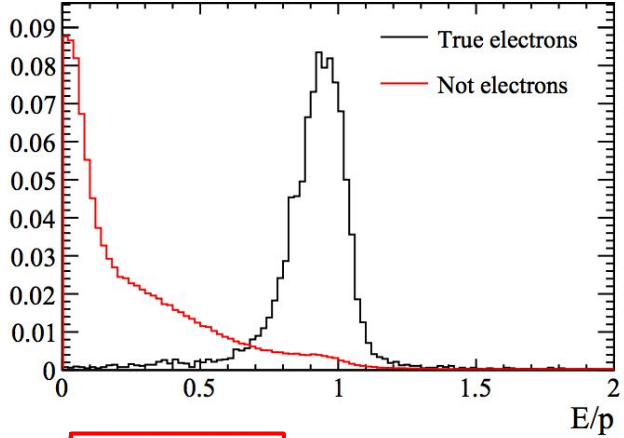
- Photon and neutral pion reconstruction: LHCb-2003-091
- Calorimeter PID: LHCb-2003-092
- Towards the upgrade: LHCb-INT-2019-027

Hlt1 electron line

M. Schubiger

Use selective track matching in Hlt1 to improve $e^{\pm}$ efficiency





Sample	Sel. eff.	Sel. eff.
$B^0 \to K^* ee$	48%	64%
$B^0 \to K^* \mu\mu$	67%	69%
MinBias	12%	17%

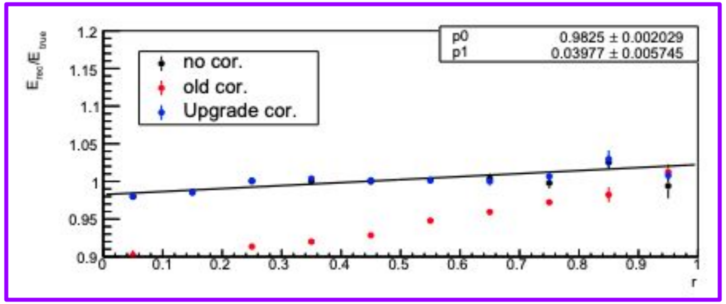
checks and timing improvements ongoing

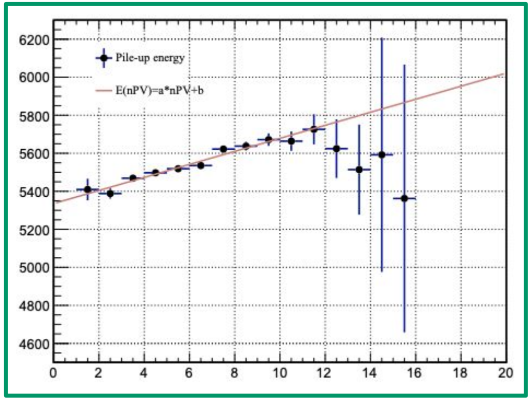
Cluster corrections: E

Derived by C. Normand and S. Zenaiev for Run 3, ongoing validation by P. Garica

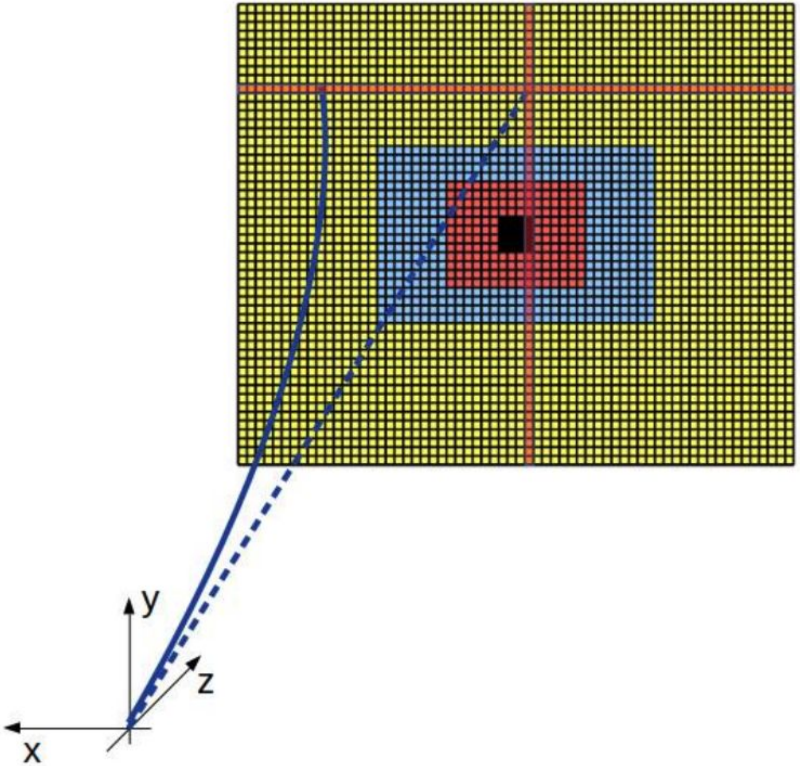
3x3 mask gives biased measurement of energy:

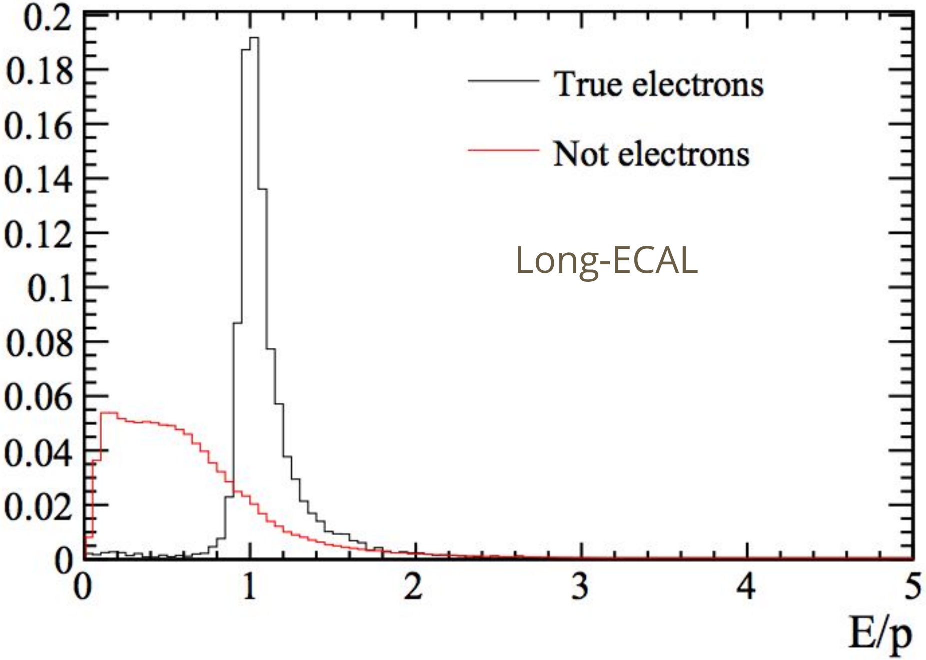
- pile-up: higher in Run 3, no SPD information → param f(nPV, cellID)
  - already in database, improvements still possible
- leakage: $E = \alpha_1(E_{3x3}) \cdot \alpha_2(r_{b/cluster}) \cdot \alpha_3(r_{b/module})$ on top of pile-up
  - $\alpha_1 < 1\%$, α_2 opposite than Run 1, to be understood
  - not yet in database





Velo-ECAL matching





Electron reco: Velo-Ecal matching (WIP)

Maxime, Wouter, details here

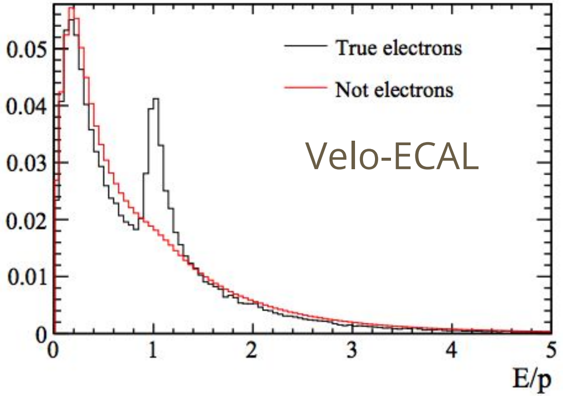
Extrapolate track state at end of Velo to ECAL

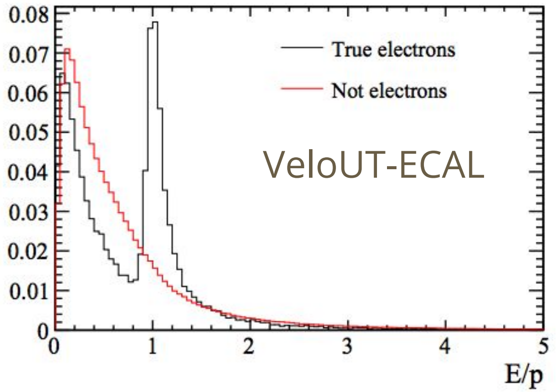
- Brem cluster should match x and y projection
- $e^{\pm}$ cluster should match y (bending only in x)
- estimate q/p from cluster position

Can select 30% signal but some fake rate

Velo-ECAL w Brem	10491 (52%)	20032 (66%)
Velo-ECAL w/o Brem	5695 (28%)	2910 (34%)
VeloUT-ECAL w Brem	6952 (34%)	609 (8%)
VeloUT-ECAL w/o Brem	4248 (21%)	318 (7%)

$B_d \to K^*ee$ upgrade MC





Electron reco: seeding (WIP)

Louis, Mengzen, Vava, Carla, details here and here

Seeding efficiency worse for electron tracks

- 3-track combination: 5% loss for long electrons → recovery step with larger search windows
- fit model deviates from quadratic for electrons that emit brem in SciFi